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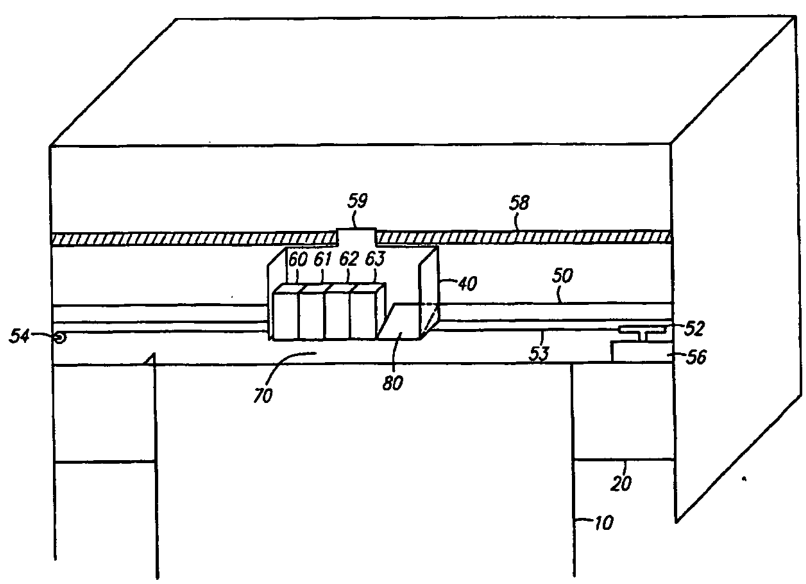

(57) Abstract

A printing system comprises a print carriage (40) with at least two printheads (60, 61) located on the print carriage. At least one nozzle is located on each of the printheads. Each nozzle discharges ink from the printhead, in response to a signal from the printing system. A densitometer (80) located on the print carriage, is capable of measuring printed image density for different ink colors and the densitometer includes an edge type and detector that determines a type of the media.

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DESCRIPTION

Carriage Mounted Densitometer

Field Of The Inventions

The inventions relate to the field of printing systems, and more specifically to ink jet printing systems.

Background Of The Inventions

An ink-jet printing system is a type of non-impact image recording device that forms characters and images on a medium by controllably discharging ink from printheads or cartridges disposed on a print carriage. Two well known types of ink-jet printing systems are printers and plotters. In one type of ink-jet printing system the print carriage includes multiple printheads or cartridges (referred to herein as the Printheads) each of which is dedicated to printing a specific color. The colors are generally magenta, cyan, yellow and black. These colors are selected because their combinations can yield a wide range of colors.

Each printhead controllably ejects ink in the form of droplets through either a single nozzle or through multiple nozzles, depending on the type of printhead. The ejected droplets travel through an air gap and onto the media. Shortly thereafter, the ink droplets dry on the medium to form images or words through their combination.

Printhead apparatuses attempt to generate variable volume ink drops using various methods. In one example the amplitude or shape of an electrical drive signal which is applied to the ink jet printer transducers is manipulated to vary the volume of the ink drop. An example of such a method and apparatus is disclosed in copending U.S. Patent

Applications Serial No. 08/808,608, which is incorporated herein by reference in its entirety.

The one or more printheads employed in printing systems may have life expectancies that are considerably less than that of the entire printing system. Therefore, the printheads may be designed to be replaceable during the life of the printer system.

A known drawback of ink-jet printing systems is that printheads will discharge different droplet volumes and densities at different times, even in response to a signal instructing the same amount of discharge. In general, the absolute volume of ink ejected from the printhead is not well controlled, and may vary with time, ambient temperature, or other environmental factors. Also, the use of different combinations of ink and media by the user may result in prints which are too light or dark.

Another problem associated with ink jet printing systems is that changes in the ambient temperature or other environmental factors can affect discharge volume and print quality.

Variations in the volume of ink discharged from the printheads result in the printing of lesser quality images on the medium since the expected volume of ink is not discharged. Thus, images can be less or more dense than expected, or the color tones can be different than those which were desired by the user.

Therefore, it is desirable to create a printer that can monitor and adjust the amount of ink discharged by a printhead in response to environmental conditions.

Prior art color densitometers which are used to monitor ink discharge utilized incandescent light sources and a number of color filters to block light having different wavelengths from the color of interest. However,

incandescent light sources generally operate at filament temperatures between two thousand and three thousand degrees Kelvin and therefore have a limited life span. High temperatures generated by the light source can cause premature aging of the entire apparatus. An additional problem with operating at these high temperatures is that they may affect the optical sensors and sensitive electronics used to measure the reflected light.

Another major factor affecting the amount of ink that is discharged upon the media is the media type on which images are being printed. For instance, a glossy media type will require a different amount of ink than a paper type media to create the same image. Therefore, it is desired that a printing system be able to automatically compensate for characteristics of the media type inserted used.

In addition to the above, it can be desirable to have a single printing system which has the ability to print on media having different sizes. The size may be variable in both length and width, or in length or width individually. Determination of the media size by the printing system can be input by the user through a printer interface. Such an interface can be a key pad on the printer, an on-screen menu on a computer or other input devices. However, it would be desirable to have a printer which can automatically determine the size of the media and print images with consistent quality on media of different sizes without user intervention.

Summary Of The Invention

A printing system comprises a printing mechanism adapted for printing on a substrate, a first light source adapted for emitting light onto a surface of the substrate, a second light source adapted for emitting light onto the

surface of the substrate, and a photosensor adapted to detect light emitted by the first light source and the second light source which is reflected from the surface of the substrate.

One aspect of the printing system includes a carriage mounted densitometer. The densitometer is preferably designed to detect densities of inks having different colors. The densitometer is also capable of being used to determine the width of media inserted into the printing system, as well as the type of media.

Another aspect of the present invention comprises a print carriage including at least two printheads, each of the at least two printheads discharging ink of a different color onto a media. A densitometer for measuring a separate ink density for each ink color discharged from the at least two printheads onto the media, the densitometer comprising a media type detector that determines a type of the media.

Yet another aspect of the present invention comprises a method for calibrating ink discharge levels in a printing system, by printing a test pattern on a media in the printing system, the test pattern comprising at least two areas each being a different color; illuminating the test pattern with light; detecting an intensity of the light after reflection from the test pattern; converting the intensity into an electrical signal; and altering the amount of ink discharged on a next discharge according to the intensity of the light determined.

In another aspect the present invention is directed toward a non-impact printing system. The non-impact printing system comprises a platen, a guide rail disposed above the platen, a print carriage disposed upon the guide rail, at least two printheads, each of the at least two printheads discharging ink of a different color onto a

media. The printing system also includes a densitometer, the densitometer measuring a separate ink density for each ink color discharged from the at least two printheads onto the media. The densitometer also includes comprising a media type detector that determines the type of the media. The printing system further includes means for moving the print carriage along the guide rail.

In yet another aspect of the present invention the densitometer is capable of acting as a media width detection system for extremely glossy and matte-surface media.

The above and other preferred features of the invention, including various novel details of implementation and combination of elements will now be more particularly described with reference to the accompanying drawings and pointed out in the claims. It will be understood that the particular methods and structures embodying the invention are shown for illustration only and not as limitations of the present invention. As will be understood by those skilled in the art the principles and features of the invention may be employed without departing from the scope of the invention.

Brief Description Of The Drawings

Reference is made to the accompanying drawings in which are shown illustrative embodiments of aspects of the invention, from which novel features and advantages will be shown.

Fig. 1 is a front perspective of a preferred embodiment of a printing system constructed according to the present invention.

Fig. 2 is a side elevational view of a preferred embodiment of a preferred densitometer apparatus constructed according to the present invention.

Fig. 3 is a view of a surface of a preferred densitometer apparatus.

Fig. 4 is a diagram showing the angle of incidence and reflection for a preferred densitometer.

Fig. 5 is a block diagram of the preferred electrical components of a densitometer apparatus constructed in accordance with the present invention.

Fig. 6 is a diagram of a preferred calibration system.

Fig. 7 shows a preferred test pattern for determining the density of an image area on the media using the preferred densitometer apparatus.

Fig. 8 is a flow chart of the operation of a preferred color densitometer.

Fig. 9 is a flow chart showing calibration of a preferred printing system.

Fig. 10 is a top view of a preferred apparatus for determining the location of an edge of a diffuse surface media.

Fig. 11 shows the angles of incidence and reflection for a preferred embodiment of a preferred edge detection system used for glossy media.

Fig. 12 is a flow chart showing the operation of a preferred media width detection system.

Fig. 13 is a flow chart showing the operation of a preferred media type detection system.

Description Of The Drawings

Referring to Fig. 1, a printer 5 is shown. Medium 10 is disposed on the surface of platen 20. Platen 20 is disposed inside printer 5. The platen 20 defines the maximum width of media that can be inserted into printer 5. Print carriage 40, which is above platen 20, is slidably

connected to a guide rail 50. Print carriage 40 moves along guide rail 50 in a direction substantially perpendicular to the movement of media 10 being fed through the printer 5. Movement of print carriage 40 is accomplished by mechanical drive assembly 52, which includes a wire, chain, belt or the like 53 mechanically coupled to print carriage 40, and wound around opposing pulleys 54, and a motor 56 which powers one of the pulleys. Many other configurations of mechanical drive assemblies are useable with the present system.

A code strip 58 having a plurality of equally spaced markings 57 thereon is disposed along the width of printer 5 and above guide rail 50. Code strip 58 contains positional information which is read by an encoder module 59 on print carriage 40. The encoder module 59 preferably includes an optical reader that uses the markings 57 provided on code strip 58 to determine the appropriate position for discharging ink in response to appropriate commands. Although only one arrangement of code strip 58 and encoder module 59 is shown, any other configuration that can be used with a print carriage can be used by the present invention without deviating from the scope and teachings of the present invention.

Print carriage 40 preferably includes a first printhead 60, a second printhead 61, a third printhead 62, and a fourth printhead 63. In a preferred embodiment, each printhead 60, 61, 62, and 63 is dedicated to ejecting ink of a different color. The printheads 60, 61, 62, and 63 can be arranged in a variety of configurations. Possible arrangements of the printheads 60, 61, 62, and 63 include a single horizontal row aligned along the axis of guide rail 40, two side-by-side vertical columns, a matrix configuration or any other configuration that is capable of creating uniform images on a media. The presently preferred

alignment of printheads 60, 61, 62, and 63 is a single horizontal row aligned parallel to the guide rail 50, with each printhead being slightly offset from its nearest neighbor.

Each individual printhead 60, 61, 62, and 63 is selectively used to discharge ink. The ink which is discharged from the printheads 60, 61, 62, and 63, travels through an air gap 70 in the form of droplets until striking the media 10. The droplets of ink discharged are substantially spherical in shape prior to the moment that they come in contact with the media 10. The size of the droplets is relatively small compared to size of the paper. In a presently preferred embodiment, the printer or plotter delivers a resolution of 360 or 720 dpi (Dots Per Inch).

The printheads are preferably of a piezoelectric type which eject ink in response to mechanical deformation of the printhead structure upon the application of electrical signals. A preferred embodiment of a printhead is disclosed in copending U.S. Patent Application Serial No. 08/703,924, entitled "Ink Jet Printhead Apparatus", and is hereby incorporated herein by reference in its entirety.

Mounted adjacent to and in substantial alignment with the printheads 60, 61, 62 and 63 is a densitometer 80. Densitometer 80 can be used for performing multiple functions, including determining the density of a particular pattern printed on the media. As will be described in greater detail below, the density of a particular ink pattern is a measurement that is represented by the negative logarithm of the average reflectance over an area on the media. The density information as measured by densitometer 80 can in turn be used to calibrate the amount of ink discharged from a particular printhead 60, 61, 62, or 63.

Because it is carriage mounted, densitometer 80 can be used to calibrate the color at any time without having to remove the media from the printer to use an external densitometer. This saves time because a shorter interruption of the printing process is required since the printer need not be stopped to remove the paper to take the measurement. Another advantage is that a carriage-mounted densitometer saves the user the need of purchasing, using and retrievably storing additional external hardware to measure ink density. Further, the costs and time for printing is decreased since operator time and cost are no longer required for the process.

Referring to Fig. 2, the interior of densitometer 80 preferably comprises a first light source 100, a second light source 110, and a third light source 120. In a presently preferred embodiment, light sources 100, 110, and 120 are light emitting diodes (LEDs). However, light sources 100, 110, and 120 can be photoemmiters, laser diodes, super luminescent diodes, fiber optic light sources, or other suitable light sources. The light sources preferably have an emitted spectrum with strong peaks in the red, green or blue wavelengths of the visible light spectrum. The light sources 100, 110 and 120 emit light signals which are reflected by the surface of the media and detected by photosensor 130. The amount of light reflected by the surface of the media is proportional to the average reflectance of the pattern printed thereon. In a preferred embodiment, photosensor 130 is a light-to-frequency converter. A light-to-frequency converter will output a signal with a frequency proportional to the intensity of the detected light. One such light-to-frequency converter is a TSL235 photosensor manufactured by Texas Instruments, Corp. It is possible, however, to construct photosensor 130 with

photo diodes, logarithmic amplifiers and A/D converters in combinations which could be created by one skilled in the art. An advantage of using light-to-frequency converters includes their compact size and the reduced cost of using a single component instead of a multi-component apparatus. Further, the use of A/D converters and log amplifiers increases the difficulty of device calibration, as well as making the device more sensitive to temperature changes. However, any apparatus which can generate an electrical signal in response to light can be used by the present invention without deviating from the scope and teachings of the present invention.

The output of photosensor 130 is input to a frequency counter 140. Frequency counter 140 determines the intensity of the light received by the photosensor 130 by counting the number of pulses within a specific time period. In a preferred embodiment, frequency counter 140 is a Peripheral Interface Controller (PIC) 16C74 manufactured by Microchip Technology, Inc. However, it will be apparent to those skilled in the art that any apparatus which can accurately determine the intensity level of electrical signals that are produced by a photosensor can be used by the present invention. Frequency counter is preferably located on the print carriage 40, but can be located anywhere within printer 5.

The magnitude of the intensity of the light detected by photosensor 130 is proportional to the reflectance of the pattern printed on the media. That is, the lesser the ink density on the medium, the greater the magnitude of the reflected light intensity detected by the photosensor. The resulting light intensity levels can be used to calibrate the amount of ink that should be discharged from a printhead or the number of ink droplets printed in a given area to

obtain the desired printed density for the specific image. The intensity can either be maintained as a reflectance value or converted into a density value depending on the software, drivers and/or system used.

Densitometer 80 further includes an additional light source 150. The specular reflections of light emitted by the additional light source 150 are capable of detection by photosensor 130. The additional light source 150 can be used to determine the width of the media inserted into printer 5, as will be described with respect to Fig. 13 below.

Referring to Fig. 3, a perspective view of the underside (i.e. the side which faces the printing media) of a preferred densitometer 80 is shown. First light source 100, second light source 110 and third light source 120 are the three light sources that are included in a preferred densitometer 80. The light sources are preferably aligned with respect to photosensor 130 so that a substantial portion of the light that is detected by the photosensor is a diffuse reflection from the media 10 of light emitted by the light source 100, 110 or 120. The alignment of each light source 100, 110, and 120 is preferably less than fifteen degrees (15°) from a line perpendicular to the surface of the media 10, as shown in Fig. 4.

First light source 100, second light source 110, and third light source 120 are preferably light emitting diodes that each emit a light signal of a different wavelength and therefore a light signal of a different color. The light emitting diodes preferably emit light in a narrow frequency band associated with the specific color (The band is preferably 10nm for each color). The use of light emitting diodes prevents several problems associated with

incandescent light sources used in standard densitometers such as limited lifetime and color drift with time.

Preferably, the colors selected for the light sources are strongly absorbed by an ink color used in the printer, then the selection is made such that for every color of ink, there is one light source color which has a wavelength that is substantially absorbed by the ink color. A preferred densitometer uses only three color diodes since the color black is actually the absence of all color (i.e. it absorbs all wavelengths of light) and any of the three diodes can be used when calibrating black ink patterns or printheads. A presently preferred correspondence of light emitting diodes to ink colors is shown in Table 1 below.

Table 1

Printhead Color	Corresponding Light Emitting Diode Color Used
Cyan	Red (Wavelength between 630 nm and 750 nm)
Magenta	Green (Wavelength between 490 nm and 570 nm)
Yellow	Blue (Wavelength between 450 nm and 490 nm)
Black	Red (Wavelength between 630 nm and 750 nm)

As can be seen, the system can be readily adapted to be used with a single color printer by using only one light source to measure density. For instance, an ink jet printer which only uses black ink can use a red light emitting diode for density measurements. Further, an additional light source 150 is arranged at an equal angle to the media as the

detector can be retained on the densitometer for purposes of retaining the functionality of the system as a whole.

The printer or plotter is under the control of a computer controller (referred to herein as the controller). Referring to Fig. 5, a block diagram of the control system used with the present invention is shown. Controller 300 can be comprised of a microprocessor, microcontroller, software, memory, or any combination of these components. Controller 300 directs operation of the printer 5. Examples of such functions include controlling the amount of ink emitted by the printheads 60, 61, 62, and 63, movement of the carriage 40, the timing (i.e., when the light sources are turned on and for how long), the amount of light emitted by the light sources 100, 110, and 120, and the editing of a tonal pattern look up table for the tonal adjustments (which is discussed below).

In a preferred embodiment, controller 300 operates frequency counter 130, and the light source driver 310. However, the functions of the frequency counter 130 and the light source driver 310 can be performed by separate components if desired. In a preferred embodiment, the light sources 100, 110, and 120 emit light for a fixed period of time. In a preferred embodiment, this fixed period of time is a whole number multiple of a half cycle of the Alternating Current ("A/C") mains power supply signal. This is done to compensate for the flicker of the lights in the room in which the printer operates, which are also reflected from the surface of the media and generally operate using the same A/C mains power supply signal. While a light source 100, 110 or 120 emits light for the fixed period, the light is reflected from media 10 and detected by photosensor 130. The photosensor 130 then creates an electrical signal with a frequency proportional to the

intensity of the reflected light. The output signal from the photosensor 130 feeds the frequency counter 140. Frequency counter 140 transmits information corresponding to the light intensity to controller 300 which uses the transmitted information to calibrate the printing system.

Referring to Fig. 6, a tonal value look up table 450 is shown which provides the density correction control signals for driving printer 5. A preferred tonal value look up table 450 comprises a first tonal value look up table 452, a second tonal value look up table 453, a third tonal value look up table 454 and a fourth tonal value look up table 455, where each tonal value look up table 452, 453, 454, 455 corresponds to a specific ink color used in a printhead. The tonal value look up table 450 can be initially a set of preprogrammed values, or can be calculated as a first step prior to printer use. Tonal value look up tables 451-454 are created by various algorithms using the information obtained from densitometer 80. Tonal value look up table 450 can reside in a general purpose computer memory magnetic storage, or any other storage media accessible to the controller 300. The information contained in tonal value look up table 450 is used to determine the ink discharged, and is variable and dependent on the latest calibration values.

To more accurately calibrate the ink discharge for each printhead, it is preferred that a test pattern 500 be printed on the media 10 which is the same for each density calibration operation. In Fig. 7, a preferred test pattern 500 is shown. Preferably, swaths 510, 520, 530 and 540 is created for each color, with each individual patch having a different density. The density is determined by the number of dots created by ink discharge in a specific area. The number of patches created for each color is preferably the

same, although it is possible to use a different number of patches according to user or printer specification. Preferably, as shown in Fig. 7, twelve patches of varying densities for each color are created within one swath. The preferred densities of the test patterns for each color are tonal values of approximately 0%, 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95% and 100% of the maximum printed density. The patches preferably have an area large enough to allow the densitometer 80 take a density or reflectance reading.

A preferred method for calibrating an ink jet printer is disclosed in Fig. 8. A calibration command is input to the printer (Step 600). The calibration command can be input by a user at any time, a regular function performed by the printer at power up, a regular function when new media or ink is placed in the printer, or, when the halftone screen patterns or printed resolution are changed and/or performed at specified time intervals during printer use. Upon receiving the calibration command (Step 605), the carriage is moved to a position above the media and the photosensor determines the intensity of the light reflected from the media prior to using any of the light sources 100, 110, and 120 (Step 610). Step 610 is not always necessary and may be substituted by measuring the reflectance. However, step 610 is preferred since any reflectance that is a result of the ambient light should be subtracted from the any values obtained during calibration. Next, the requisite number of patches for each color are printed upon the media (Step 620), see Fig. 7. The densitometer 80 is then positioned above a swath (Step 630). After densitometer 80 is properly positioned, the appropriate light source 100, 110 or 120 is illuminated (Step 640). The diffuse reflection is detected by the photosensor 130 for the

particular illuminated light source (Step 650). The process is then repeated for each patch of a same color (Step 660). After the density for all the patches of a color has been determined, the tonal value look up table for each color is created (Step 670). The process is then repeated for each color.

The tonal value look up table preferably contains a series density increments or reflectance increments and a corresponding print value for each density increment or reflectance. The density increments or reflectance increments are variable and a function of the system and software used. A preferred density look up table contains 256 density increments. The print value represents the percentage of dots per square inch that are required to achieve the corresponding density increment. The print value is used by the computer or work station during rasterization of an image to determine the amount of ink to discharge at various positions on the media.

Referring to Fig. 9, after obtaining density values for all the test patches in a particular test swath of a particular color, the measured density values are matched with the appropriate print value (Step 675). These measured density values are then stored as the density values for the appropriate print value (Step 680). The remaining density values for the density values which were not one of the tonal values printed are obtained using interpolation (Step 685). The print values can be calculated using methods which are known to one of skill in the art. Alternatively, the system can operate using reflectance values as opposed to density values. In this situation, the tonal correction look up tables are created and function using reflectance values. The use of reflectance measurements are preferred over density measurements, since the output of the frequency

counter 140 is in fact a reflectance intensity, and converting the reflectance intensity values into a density value requires processing overhead.

The process described above is a presently preferred embodiment of the invention. Various modifications to the process are possible without departing from the invention. For instance, it is possible that patches for each color are printed only after the tonal value look up table for a prior color has been created. Additionally, if the printing system uses only one color then only one set of patches for that one color need to be printed and tested.

Referring to Fig. 10, it can be seen that diffuse reflections 700, but not the specular reflections 710 created by first light source 100, second light source 110, and third light source 120, are detected by photosensor 130. A diffuse reflection is one where the angle of incidence for all the rays of light is different than the angle of reflection. Conversely, a specular reflection is one where the angle of incidence is exactly equal to the angle of reflection. Since media surfaces are generally "rough" (not mirror like), there is always some diffuse reflection decreased by photosensor 130, even when the additional light source 150 is used.

The diffuse reflections 700 can be used to determine whether or not there is media in the printer as well as to determine the position of the edge of the media. However, not all media produce sufficient diffuse reflections using the geometry of the preferred densitometer. For instance, transparent media (such as Mylar) produce little if any diffuse reflections which could be detected by photosensor 130. Such a media, however, can produce sufficient specular reflections that are detectable by the photosensor. Referring to Fig. 11, additional light source 150 is used in

determining the width of media 10 in the printer 5. Specifically, additional light source 150 is aligned so that the angle of incidence 730 of the light beams emitted from additional light source 150 is approximately 45° from an axis 740 which perpendicular to the surface of the media 10. Further, this alignment allows the angle of reflection 750 to also be 45°. Therefore, the angle of reflection is approximately equal to the angle of incidence. The alignment shown in Fig. 10 allows for sufficient intensity of reflections to be detected by photosensor 130. Specular reflections of light emitted by the additional light source 150 have sufficient magnitude because the critical angle (the minimum angle of incidence at which reflection occurs) for media in current use is generally less than 45°, thereby allowing light emitted by additional light source 150 and reflected from the surface of a media to be detected by the photodetector 130.

The preferred process for determining the edge of a specific media is shown in Fig. 12. First, the media 10 is inserted into a printer or plotter (Step 800). In general, one edge of the media 10 is positioned at a known, fixed location. This known location is usually aligned with the left edge of the media. The carriage 40 is then moved to a position over the platen 20 which is left of the left edge of the media (Step 810). The light sources 100, 110, 120 and 150 are illuminated in sequence and the highest intensity of the reflection is determined (Step 820). This intensity is then used as reference value such that when the same intensity at step 820 is received again, the system can determine the edge of the media. The carriage 40 is then moved using a constant velocity along the guide rail 50. While the print carriage 40 is moved along the guide rail 50, the light source 100, 110, 120 or 150 which had the

highest intensity at step 820, produces light pulses at regular intervals. The intensity of the specular reflections are detected by the photosensor 130 (Step 830). When the intensity of the specular reflections is approximately equal to the intensity collected at step 830, it is then known that the edge of the media is found. The position of the carriage 40 is then determined by having the position encoder 59 determine the position of the carriage 40 from the code strip 58 (Step 840). The distance between the fixed edge and the carriage 40 is determined which allows the calculation of the width of the media (Step 850). Using this method, media of any width can be inserted into the printer, regardless of whether it is a standard or a non-standard size. This is due to the fact that the width of the media is actually measured. The width is not determined using a look up table of media sizes nor provided by the user.

The process described above, is a preferred embodiment of a width detection system according to the present invention. Various modifications to the process are possible without departing from the scope of the invention. For instance, it is possible that the right edge is the edge which is used as the known position. Further, it is possible that steps 840, 850 and 860 are performed simultaneously. Alternatively, any of the light sources 100, 110 or 120 can be used instead of additional light source 150 as the light source used for edge detection.

The preferred process for automatically determining the type of media inserted into the printing system is shown in Fig. 13.

At step 900, a media is inserted into the printing system by a user. Then the densitometer is moved to a position above the media (Step 910). The position where

densitometer is located can be determined by using a position which is located above the minimum media size that the printer can use. Each of the light sources 100, 110, 120 and additional light source 150 is illuminated in sequentially, and the intensity of the reflected light for each light source (Step 920). The intensity values determined at step 920 are compared to each other (Step 930). If the reflected intensity from the additional light source 150 is greater than the reflected intensity from light sources 100, 110 and 120, then media type is classified as a film type media (Step 940). If the reflected intensity from any of the light sources 100, 110 and 120 is greater than the reflected intensity from the additional light source 150, then media type is classified as a paper type media (Step 950).

Alternatively, the media type detection can be performed as a single step during the process of width detection at step 820. This can be done, since at step 820 of Fig. 12 all the light sources are illuminated and the intensity of each reflectance is obtained. This can eliminate the need for a separate media type detection process, and is preferred over using a separate process of media detection. The processes described in Fig. 12 and Fig. 13 can also be run concurrently.

While the embodiments, applications and advantages of the present invention have been depicted and described, there are many more embodiments, applications and advantages possible without deviating from the spirit of the inventive concepts described herein. The invention should therefore should only be restricted in accordance with the spirit of the claims appended hereto and is not restricted by the preferred embodiments, specification or drawings.

Claims

1. A printing system, comprising:

a printing mechanism adapted for printing on a substrate;

a first light source adapted for emitting light onto a surface of said substrate;

a second light source adapted for emitting light onto said surface of said substrate; and

an photosensor adapted to detect light emitted by said first light source and said second light source which is reflected from said surface of said substrate.

2. The printing system of claim 1, wherein light emitted by said first light source strikes said media at a first angle of incidence and light emitted by said second light source strikes said media at a second angle of incidence, and wherein said first angle of incidence is different from said second angle of incidence.

3. The printing system of claim 2, wherein said first angle of incidence is greater than said second angle of incidence.

4. The printing system of claim 1, wherein said first light source comprises a plurality of light emitting diodes.

5. The printing system of claim 4, wherein each light emitting diode of said plurality of light emitting diodes emits light of a different color.

6. The printing system of claim 1, further comprising means for determining the intensity of the detected light by said optical sensor, coupled to said optical sensor.

7. A print carriage comprising:

at least two printheads, each of said at least two printheads discharging ink of a different color onto a media; and

a densitometer, said densitometer measuring a separate ink density for each ink color discharged from said at least two printheads onto said media, said densitometer comprising a media type detector that determines a type of said media.

8. The print carriage of claim 7, wherein said densitometer comprises an edge detector that determines the width of said media.

9. The print carriage of claim 7, wherein said densitometer comprises:

a plurality of light sources each emitting light of a different wavelength, said light sources emitting light in a direction toward a surface of a media inserted into said printing system; and

a photosensor that detects reflections of said light from said media.

10. The print carriage of claim 9, wherein the plurality of light sources and photosensor are arranged so that specular reflections created by light emitted from each light source of said plurality light sources are substantially not detected by said photosensor.

11. The print carriage of claim 10, wherein each light source of said plurality of light sources is positioned to be approximately less than 15° from an axis perpendicular to the surface of said media.

12. The print carriage of claim 9, wherein each light source of said plurality of light sources comprises a light emitting diode.

13. A method for calibrating ink discharge levels in a printing system, comprising:

printing a test pattern on a media in the printing system, the test pattern comprising at least two areas each being a different color;

illuminating the test pattern with light;

detecting an intensity of the light after reflection from the test pattern;

converting the intensity into an electrical signal; and

altering the amount of ink discharged on a next discharge according to the intensity of the light determined.

14. The method of claim 13, wherein the step of altering the amount of ink discharged on a next discharge comprises a step of creating a look up table including ink ejection information for different color fill patterns.

15. The method of claim 13 wherein said test pattern comprises a plurality of swaths each having a different ink density.

16. The method of claim 13 further comprising a step of providing a calibration command to the printing system.

17. A non-impact printing system, comprising:

a platen;

a guide rail disposed above said platen;

a print carriage disposed upon said guide rail;

at least two printheads, each of said at least two printheads discharging ink of a different color onto a media;

a densitometer, said densitometer measuring an printed density for each ink color discharged from said at least two printheads onto said media, said densitometer comprising a media type detector that determines the type of said media; and

means for moving said print carriage along said guide rail.

18. The printing system of claim 17, wherein said densitometer comprises:

a plurality of light sources each emitting light of a different wavelength, said light sources emitting light in a direction toward a surface of a media inserted into said printing system; and

a photosensor that detects reflections of said light from said media.

19. The printing system of claim 18, wherein the plurality of light sources and photosensor are arranged so that specular reflections created by light emitted from each light source of said plurality light sources are substantially not detected by said photosensor.

20. The printing system of claim 18, wherein each light source of said plurality of light sources is positioned to be approximately less than 15° from an axis perpendicular to said media.

21. The printing system of claim 18, wherein each of said light sources comprises a light emitting diode.

22. The printing system of claim 17, wherein said densitometer comprises means for determining a position of an edge of said media.

23. The printing system of claim 17, wherein said densitometer comprises means for operating with media having glossy characteristics.

24. A printing system comprising:

a printing mechanism that ejects ink onto a substrate; and

means for determining the density of ink ejected onto said substrate, said means further comprising means for determining the width of said substrate.

25. The printing system of claim 24 wherein said means for determining the density further comprises means for determining a type of said substrate.

26. The printing system of claim 24 wherein said means for determining the density comprises a densitometer.

AMENDED CLAIMS

[received by the International Bureau on 28 December 1998 (28.12.98); original claim 13 amended; original claims 1-6 cancelled; new claims 27-39 added; remaining claims unchanged (9 pages)]

7. A print carriage comprising:

at least two printheads, each of said at least two printheads discharging ink of a different color onto a media; and

a densitometer, said densitometer measuring a separate ink density for each ink color discharged from said at least two printheads onto said media, said densitometer comprising a media type detector that determines a type of said media.

8. The print carriage of claim 7, wherein said densitometer comprises an edge detector that determines the width of said media.

9. The print carriage of claim 7, wherein said densitometer comprises:

a plurality of light sources each emitting light of a different wavelength, said light sources emitting light in a direction toward a surface of a media inserted into said printing system; and

a photosensor that detects reflections of said light from said media.

10. The print carriage of claim 9, wherein the plurality of light sources and photosensor are arranged so that specular reflections created by light emitted from each light source of said plurality light sources are substantially not detected by said photosensor.

11. The print carriage of claim 10, wherein each light source of said plurality of light sources is positioned to be approximately less than 15° from an axis perpendicular to the surface of said media.

12. The print carriage of claim 9, wherein each light source of said plurality of light sources comprises a light emitting diode.

13. A method for calibrating ink discharge levels in a printing system, comprising:

printing a test pattern on a media in the printing system, the test pattern comprising at least two areas, each of the at least two areas comprising a different color;

illuminating the test pattern with discreet light beams from a plurality of light sources, each of the discreet light beams having a different range of predetermined wavelengths;

detecting an intensity of each light beam after reflection from the test pattern printed on the media;

converting the intensity into an electrical signal; and

altering the amount of ink discharged on a next discharge according to the intensity of the light determined.

14. The method of claim 13, wherein the step of altering the amount of ink discharged on a next discharge comprises a step of creating a look up table including ink ejection information for different color fill patterns.

15. The method of claim 13 wherein said test pattern comprises a plurality of swaths each having a different ink density.

16. The method of claim 13 further comprising a step of providing a calibration command to the printing system.

17. A non-impact printing system, comprising:

a platen;

a guide rail disposed above said platen;

a print carriage disposed upon said guide rail;

at least two printheads, each of said at least two printheads discharging ink of a different color onto a media;

a densitometer, said densitometer measuring an printed density for each ink color discharged from said at least two printheads onto said media, said densitometer comprising a media type detector that determines the type of said media; and

means for moving said print carriage along said guide rail.

18. The printing system of claim 17, wherein said densitometer comprises:

a plurality of light sources each emitting light of a different wavelength, said light sources emitting light in a direction toward a surface of a media inserted into said printing system; and

a photosensor that detects reflections of said light from said media.

19. The printing system of claim 18, wherein the plurality of

light sources and photosensor are arranged so that specular reflections created by light emitted from each light source of said plurality light sources are substantially not detected by said photosensor.

20. The printing system of claim 18, wherein each light source of said plurality of light sources is positioned to be approximately less than 15° from an axis perpendicular to said media.

21. The printing system of claim 18, wherein each of said light sources comprises a light emitting diode.

22. The printing system of claim 17, wherein said densitometer comprises means for determining a position of an edge of said media.

23. The printing system of claim 17, wherein said densitometer comprises means for operating with media having glossy characteristics.

24. A printing system comprising:

a printing mechanism that ejects ink onto a substrate; and

means for determining the density of ink ejected onto said substrate, said means further comprising means for determining the width of said substrate.

25. The printing system of claim 24 wherein said means for determining the density further comprises means for determining a type of said substrate.

26. The printing system of claim 24 wherein said means for determining the density comprises a densitometer.

27. A printing system, comprising:

a printing mechanism adapted for printing on a surface of a medium;

a first light source that emits light within a first wavelength range onto said surface;

a second light source that emits light of a second wavelength range onto said surface;

a third light source that emits light of a third wavelength range onto said surface;

a fourth light source adapted for emitting light onto said surface; and

a photosensor adapted to detect reflections from said surface of light emitted by said first light source, said second light source, said third light source and said fourth light source.

29. The printing system of claim 28, wherein light emitted by said first light source strikes said surface at a first angle of incidence, light emitted by said second light source strikes said surface at a second angle of incidence, light emitted by said third light source strikes said surface at a third angle of incidence, and light emitted from said fourth light source strikes said surface at a fourth angle of incidence.

30. The printing system of claim 29 wherein said first angle of incidence and said third angle of incidence are different from said second angle of incidence.

31. The printing system of claim 29 wherein said first angle of incidence is substantially the equal to the third angle of incidence.

32. The printing system of claim 29 wherein said fourth angle of incidence is different than said first angle of incidence, said second angle of incidence and said third angle of incidence.

33. The printing system of claim 32 wherein said fourth angle of incidence is larger than said first angle of incidence, said second angle of incidence and said third angle of incidence.

34. The printing system of claim 33 wherein said first angle of incidence is approximately fifteen degrees from an axis which is substantially perpendicular to said surface, said second angle of incidence is approximately zero degrees from an axis which is substantially perpendicular to said surface, said third angle of incidence is approximately fifteen degrees from an axis which is substantially perpendicular to said surface, and said fourth angle of incidence is approximately forty five degrees from an axis which is substantially perpendicular to said surface.

35. The printing system of claim 27 wherein said first photodetector, said second light source and said fourth light source are arranged along a first plane.

36. The printing system of claim 35 wherein said first light source, said second light source and said third light source are arranged along a second plane, said second plane being substantially perpendicular to said first plane.

37. The printing system of claim 27, wherein said first light source comprises a plurality of light emitting diodes.

38. The printing system of claim 37, wherein each light emitting diode of said plurality of light emitting diodes emits light of a different color.

39. The printing system of claim 27, further comprising means for determining the intensity of the detected light by said optical sensor, coupled to said optical sensor.

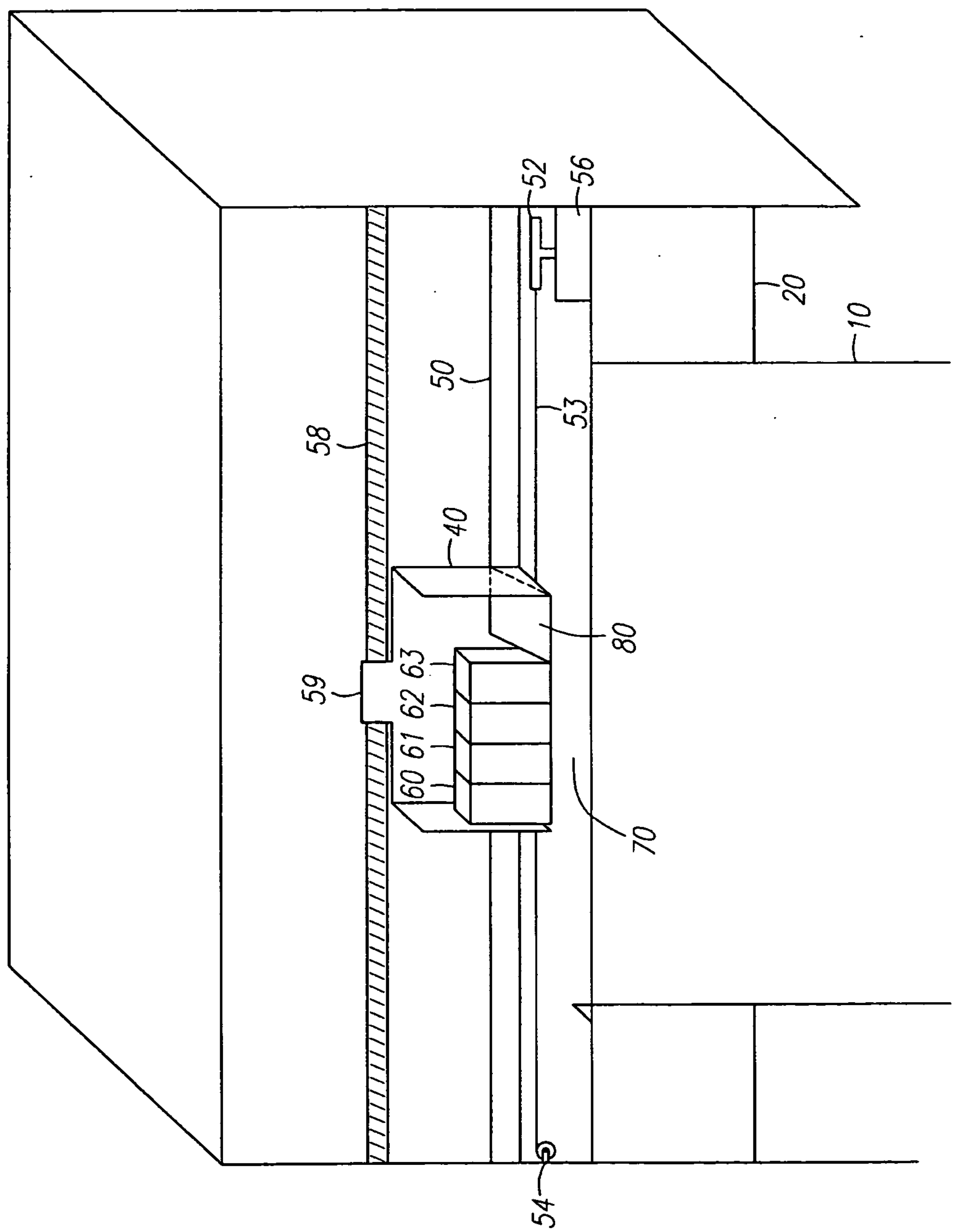

FIG. 1

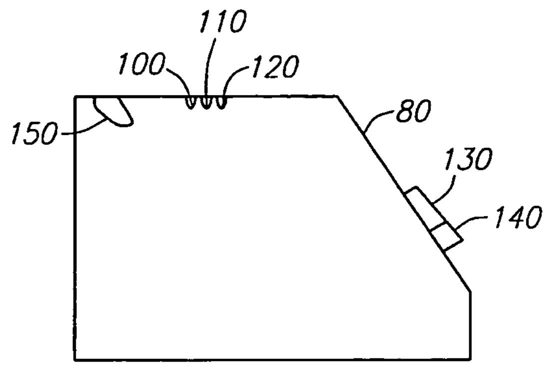

FIG. 2

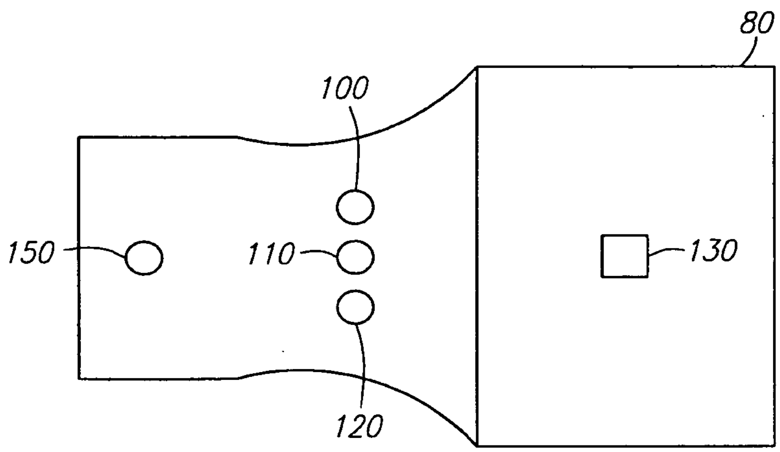

FIG. 3

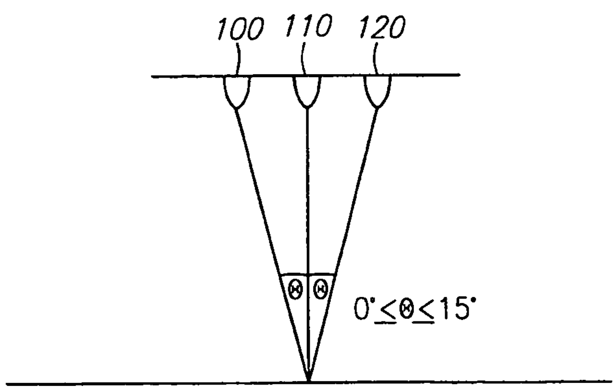

FIG. 4

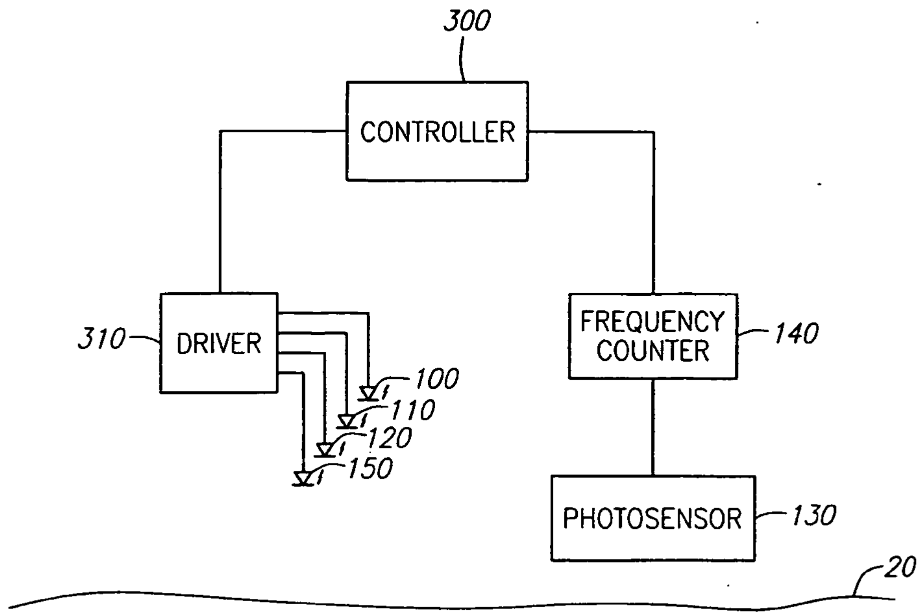
300
CONTROLLER
310
DRIVER
FREQUENCY COUNTER
140
100
110
120
150
PHOTOSENSOR
130
20

FIG. 5

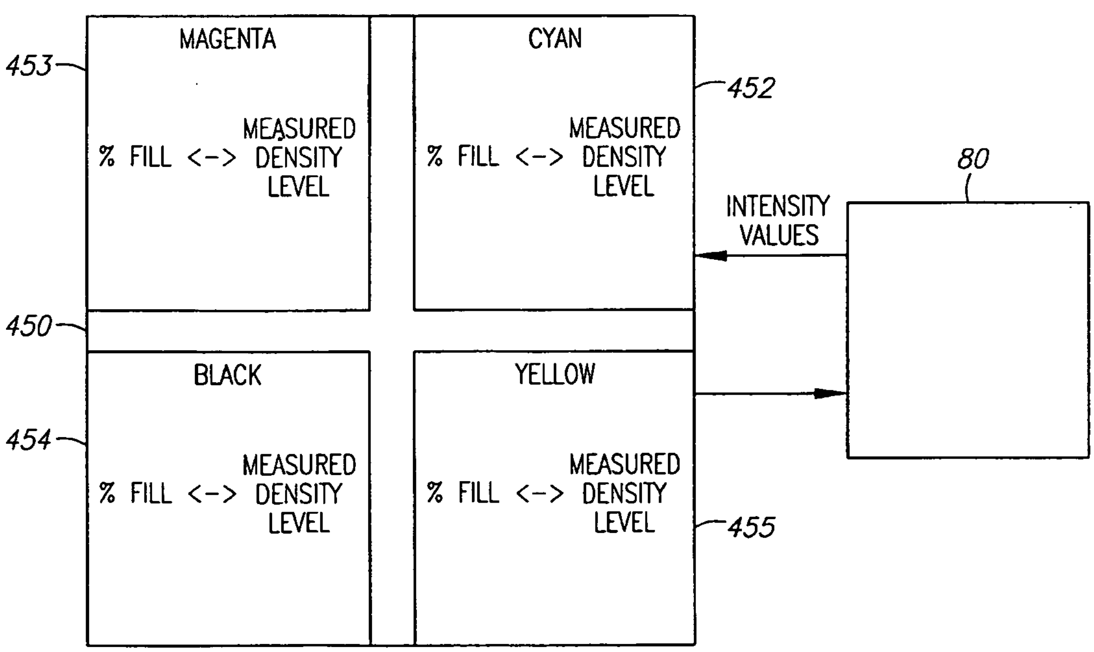
MAGENTA
% FILL <-> MEASURED DENSITY LEVEL
CYAN
% FILL <-> MEASURED DENSITY LEVEL
BLACK
% FILL <-> MEASURED DENSITY LEVEL
YELLOW
% FILL <-> MEASURED DENSITY LEVEL
453
452
450
454
455
80
INTENSITY VALUES

FIG. 6

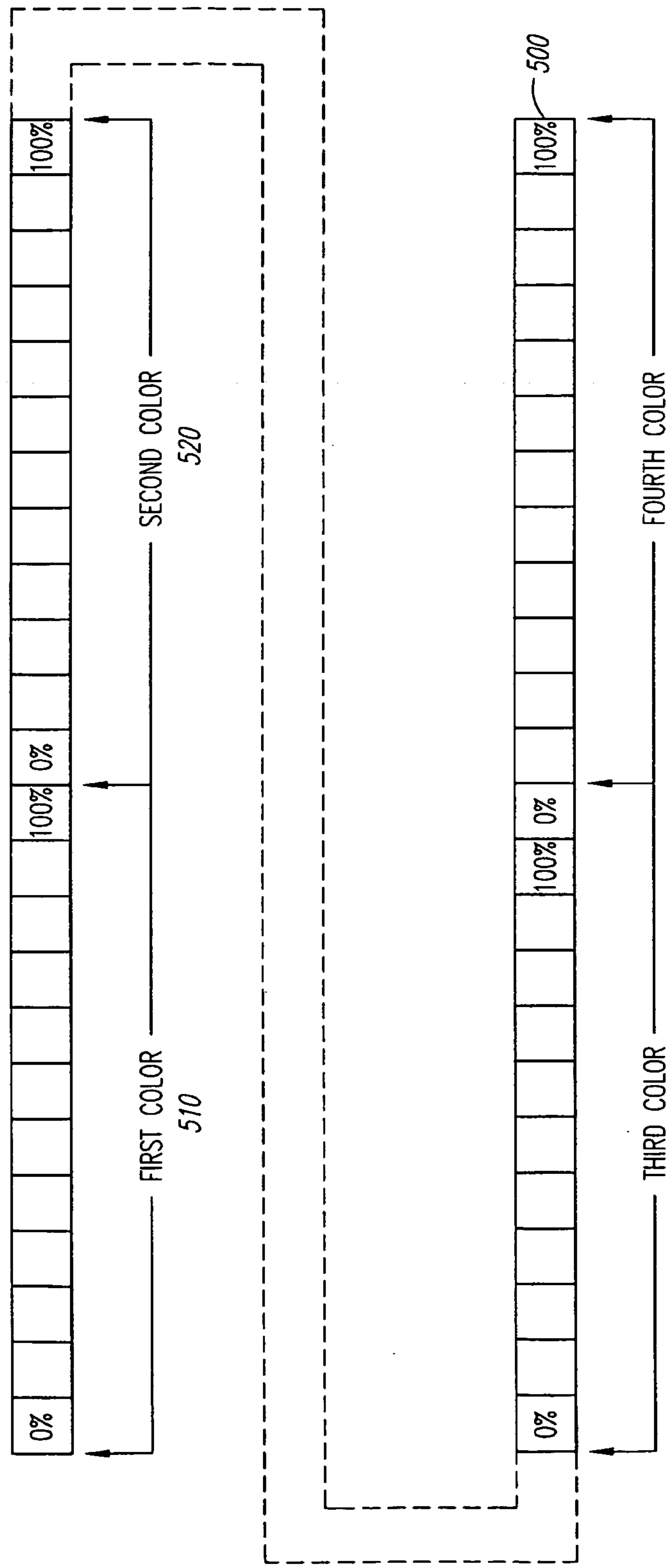
500
100%
0%
100%
0%
SECOND COLOR
520
FIRST COLOR
510
100%
0%
100%
0%
FOURTH COLOR
540
THIRD COLOR
530

FIG. 7

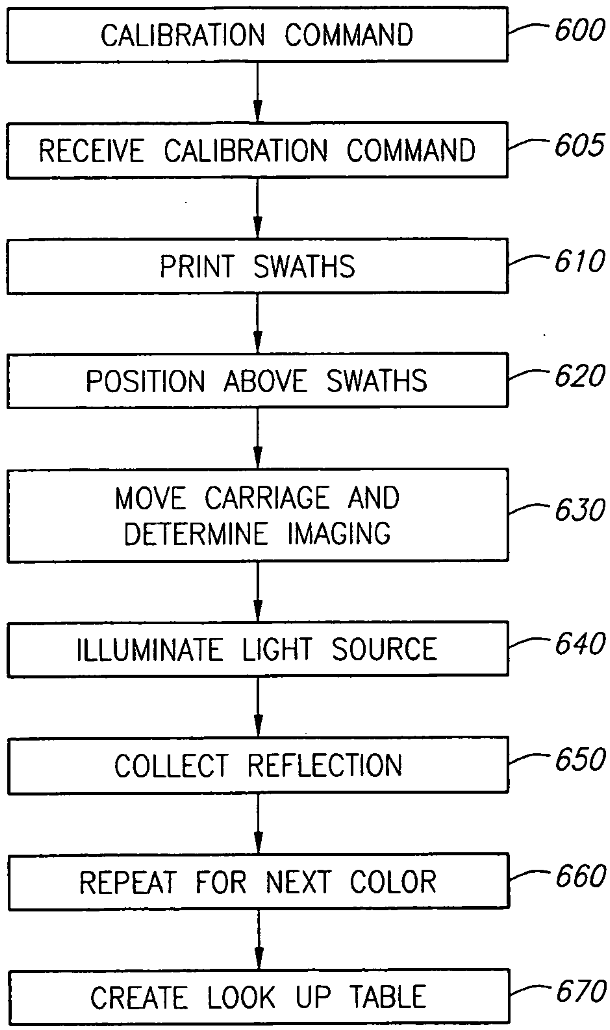
CALIBRATION COMMAND
600
RECEIVE CALIBRATION COMMAND
605
PRINT SWATHS
610
POSITION ABOVE SWATHS
620
MOVE CARRIAGE AND DETERMINE IMAGING
630
ILLUMINATE LIGHT SOURCE
640
COLLECT REFLECTION
650
REPEAT FOR NEXT COLOR
660
CREATE LOOK UP TABLE
670

FIG. 8

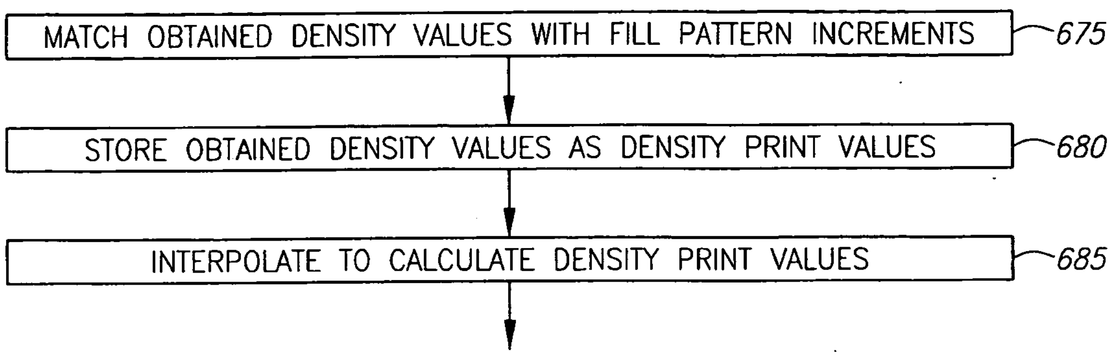
MATCH OBTAINED DENSITY VALUES WITH FILL PATTERN INCREMENTS
675
STORE OBTAINED DENSITY VALUES AS DENSITY PRINT VALUES
680
INTERPOLATE TO CALCULATE DENSITY PRINT VALUES
685

FIG. 9

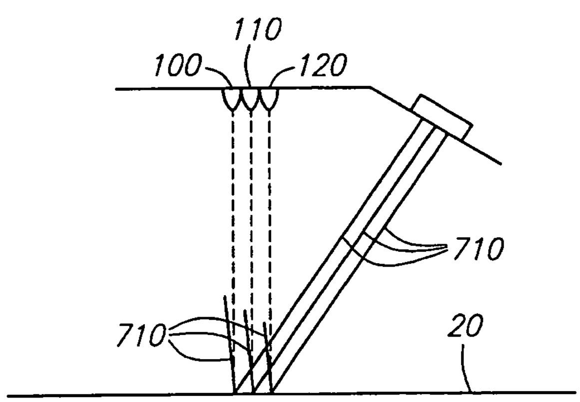
110
100
120
710
710
20

FIG. 10

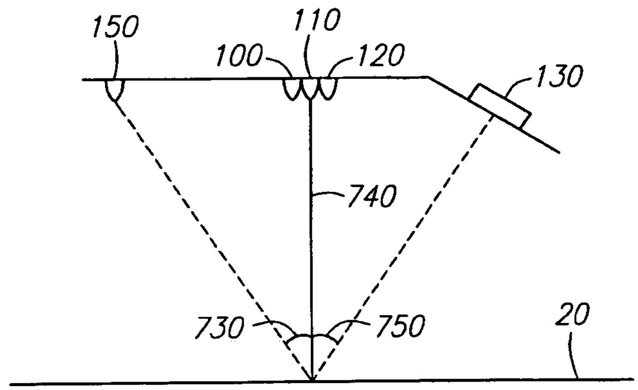
150
110
100
120
130
740
730
750
20

FIG. 11

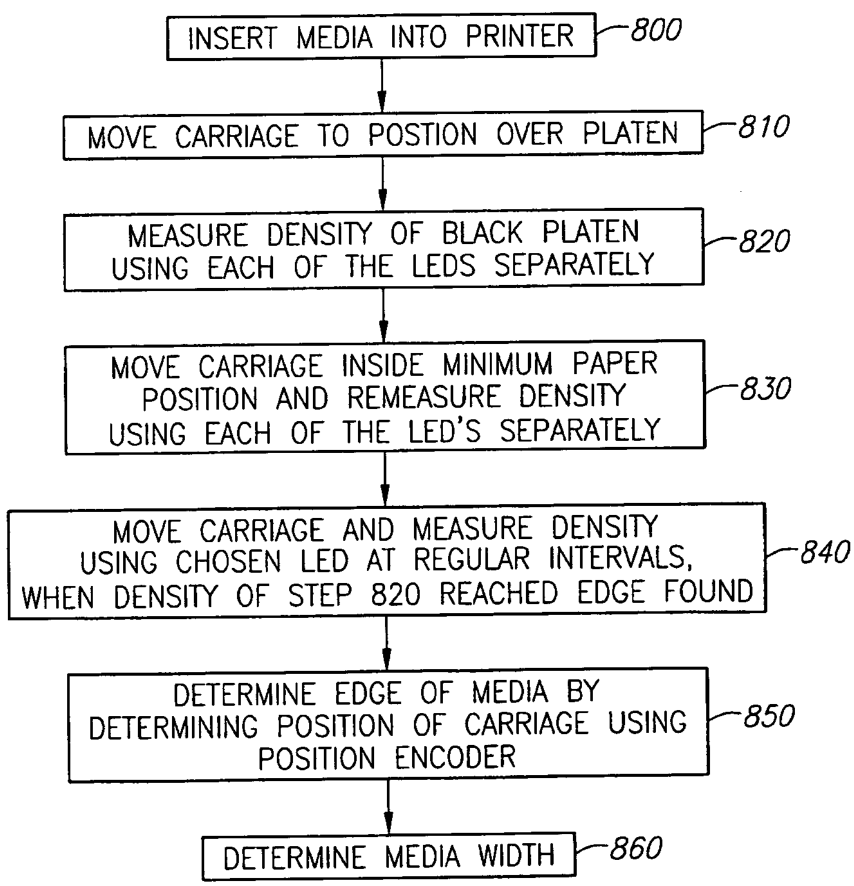
INSERT MEDIA INTO PRINTER
800
MOVE CARRIAGE TO POSTION OVER PLATEN
810
MEASURE DENSITY OF BLACK PLATEN USING EACH OF THE LEDS SEPARATELY
820
MOVE CARRIAGE INSIDE MINIMUM PAPER POSITION AND REMEASURE DENSITY USING EACH OF THE LED'S SEPARATELY
830
MOVE CARRIAGE AND MEASURE DENSITY USING CHOSEN LED AT REGULAR INTERVALS, WHEN DENSITY OF STEP 820 REACHED EDGE FOUND
840
DETERMINE EDGE OF MEDIA BY DETERMINING POSITION OF CARRIAGE USING POSITION ENCODER
850
DETERMINE MEDIA WIDTH
860

FIG. 12

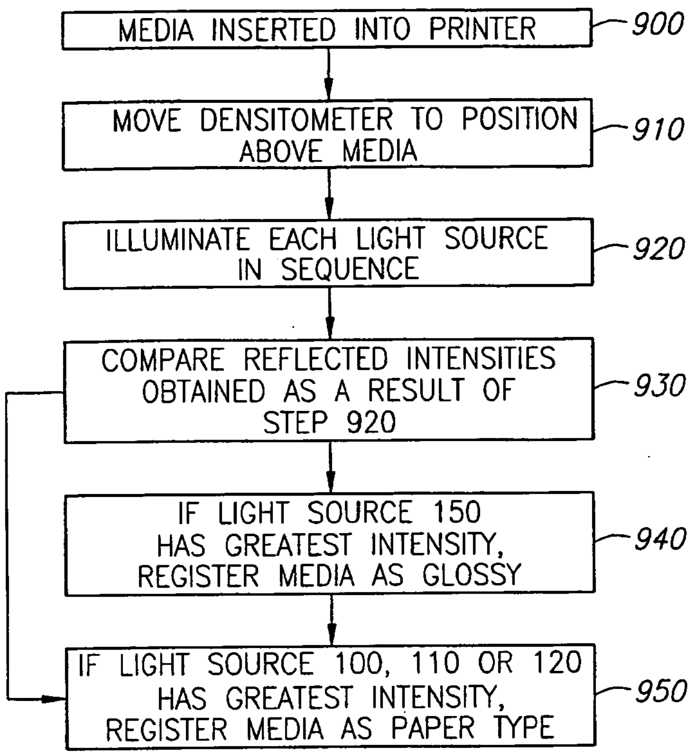
MEDIA INSERTED INTO PRINTER
900
MOVE DENSITOMETER TO POSITION ABOVE MEDIA
910
ILLUMINATE EACH LIGHT SOURCE IN SEQUENCE
920
COMPARE REFLECTED INTENSITIES OBTAINED AS A RESULT OF STEP 920
930
IF LIGHT SOURCE 150 HAS GREATEST INTENSITY, REGISTER MEDIA AS GLOSSY
940
IF LIGHT SOURCE 100, 110 OR 120 HAS GREATEST INTENSITY, REGISTER MEDIA AS PAPER TYPE
950

FIG. 13

INTERNATIONAL SEARCH REPORT

Inte. ɔnal Application No
PCT/US 98/12655

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B41J29/393 H04N1/407 B41J13/00 G01J3/46

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B41J H04N B41F G01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 008, no. 257 (P-316), 24 November 1984 & JP 59 128417 A (TOPPAN INSATSU KK), 24 July 1984 see abstract	1-6
X	PATENT ABSTRACTS OF JAPAN vol. 012, no. 107 (P-686), 7 April 1988 & JP 62 239180 A (NEC CORP), 20 October 1987	1-3
A	see abstract	4-6
X	US 4 003 660 A (CHRISTIE JR JOHN S ET AL) 18 January 1977 see the whole document	1-3
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publicationdate of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 October 1998	29/10/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Didenot, B

2

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inte   nal Application No
PCT/US 98/12655

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	DE 39 32 932 A (POLYGRAPH LEIPZIG) 11 April 1991 see the whole document ---	24
X	EP 0 604 941 A (CANON KK) 6 July 1994 see the whole document ---	13-16
X A	EP 0 665 105 A (CANON KK) 2 August 1995 see abstract see column 8, line 11 - column 27, line 21 see claims; figures ---	13-16 7,9,17, 18,24-26
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 171 (M-489), 17 June 1986 & JP 61 020780 A (SHARP KK), 29 January 1986 see abstract ---	8,24
A	EP 0 556 045 A (CANON KK) 18 August 1993 see the whole document -----	8,24

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte nal Application No
PCT/US 98/12655

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		JP 4033861 A	05-02-1992
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		DE 69128289 T	09-04-1998
		EP 0452157 A	16-10-1991
		US 5596353 A	21-01-1997
		US 5736996 A	07-04-1998
EP 0556045 A	18-08-1993	JP 5058012 A	09-03-1993
		JP 5221103 A	31-08-1993
		JP 5294023 A	09-11-1993
		JP 5330696 A	14-12-1993
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